INTRODUCTION

SCOPE AND PURPOSE OF REPORT

Investigations of ground-water in Kentucky are being made by the U. S. Geological Survey in cooperation with the Kentucky Department of Economic Development, which, until July 1, 1956, was known as the Kentucky Agricultural and Industrial Development Board. The investigations are of three types:

1. Detailed studies of ground-water conditions in small areas with special problems or problems typical of larger areas.
2. Statewide inventory of large water supplies for public and industrial use.
3. Statewide reconnaissance studies of ground water.

This atlas is a result of an investigation of the third type and is 1 of a series of 5 which will cover the entire State. The chief purpose of this atlas is to present general information on the availability of ground water in the Jackson Purchase region of Kentucky.

LOCATION AND EXTENT OF AREA

The State of Kentucky lends itself readily to a regional division based on physiography and geology. These regions are: The Eastern Coal Field, the Blue Grass, the Mississippian Plateau, the Western Coal Field, and the Jackson Purchase. The locations of these 5 regions are shown on figure 1. The boundaries as shown there are drawn on county lines which approximate, though they do not coincide exactly with, the geologic and physiographic boundaries.

The Jackson Purchase region, eight counties in the extreme western part of the State, is bounded on the north by the Ohio River, on the west by the Ohio and Mississippi Rivers, on the south by the State of Tennessee, and on the east by Kentucky Lake. This tract of land was purchased from the Chickasaw Indians in 1818 and totals 2,396 square miles.

PREVIOUS INVESTIGATIONS

One of the earliest reports describing the geology of the Jackson Purchase is that of Loughridge (1888), which contains a geologic map showing the approximate boundaries of the outcrops of the rock formations in the region. A later report by Glenn (1906) describes both the geology and the water resources of western Kentucky, western Tennessee, and southern Illinois. The water-bearing characteristics of each formation and the ground-water conditions at many cities and small towns are described in some detail in Glenn's report. Davis (1923) described the geography of the Jackson Purchase and briefly mentioned the water resources of each of his geographic divisions within the Purchase.

A report by Roberts and Gildersleeve (1950) deals mainly with geology but also contains brief descriptions of the water-bearing characteristics of the formations. This report is probably the most comprehensive study of areal geology, structure, and mineral resources yet published on the Jackson Purchase.

The first detailed ground-water report on a part of the Purchase is that of Pree and Walker (1952) on the water resources of the Calvert City-Gilbertsville area. The large public and industrial water supplies are the subject of another report by Pree and Walker (1953). Pree, Walker, and MacCary (1957) have studied in detail the ground-water resources of three 7½-minute quadrangles in the Paducah area.

METHOD OF INVESTIGATION

The fieldwork on which this report is based was done by T. W. Lambert and L. M. MacCary during the period April to October 1954. Fieldwork included making an inventory of representative wells and springs and mapping the geology of small parts of the area. The data collected on wells include measurements of depth to water and, wherever possible, discharge and drawdown (lowering of water level due to pumping). Tests of specific capacity (rate of discharge per foot of drawdown) were made on several industrial, public-supply, and domestic wells. Samples of water from each aquifer were collected for chemical analysis. Samples of sand and clay were collected from several localities for mechanical (particle-size) analysis. Well logs and drill samples were examined to obtain information from which to draw isopach and structure maps of some of the formations.

The withdrawals from domestic wells were not determined by direct measurement but were estimated on the basis of the methods of obtaining and distributing the water. If water is obtained by a bucket or hand pump, each person will use less water than well be used where water is available under pressure at the tap. A modern domestic supply, as described in this report, in one which water is delivered to the home under pressure. The maximum daily requirement of such an installation is estimated to be about 500 gallons.

This report in large part is based on information furnished by well owners, operators, and drillers. Well logs were furnished by many drillers, and drill cuttings were furnished by Messrs. R. B. Elrod, Wayne Royster, and Don Taylor.

The investigation was made under the direct supervision of G. E. Hendrickson, district geologist, Louisville. Chemical analyses of water samples were made at the district Quality of Water Laboratory of the Geological Survey at Columbus, Ohio. Mechanical analyses of sediments were made at the Hydrologic Laboratory of the U. S. Geological Survey at Denver, Colo.

GEOGRAPHY

The Jackson Purchase is a plain of low relief bounded on the east by Kentucky Lake and on the north and west by flood plains of the Ohio and Mississippi Rivers. Steep bluffs occur where the uplands terminate along the Mississippi River flood plain.

The highest hills in the Purchase are along the Tennessee Valley divide south of Lynn Grove, Calloway County, and are 640 feet above sea level. The altitude is lowest, approximately 277 feet, on the flood plain of the Mississippi River in the detached part of Fulton County.

The Purchase is drained by the Mississippi River, either directly or by way of tributaries of which the Ohio River is the largest. The largest tributary of the Ohio draining a part of the region is the Tennessee River (Kentucky Lake).

CLIMATE

The Jackson Purchase has a humid continental climate, the average annual precipitation being 45.9 inches. The average January temperature is 37° F, and the average July temperature, is 80° F. The average growing season lasts 199 days. Figure 2 summarizes the climatological data for the period 1882 to 1955. Figure 3 shows precipitation for each month from 1950 through 1954, the period of record of the hydrographs of observation wells.

MINERAL RESOURCES

The chief mineral resources of the Jackson Purchase are clay, sand, gravel, and abundant ground water. Most of the high-grade clay is used for ceramic products and refractories, and the bulk of it comes from Graves County. Brick and field-tile clay is found in most of the Purchase. Some of the inferior grades are mixed with better grades in the manufacture of ornamented pottery.

Pliocene(?) sand and gravel deposits have great extent and furnish much of the so-called bank gravel used in surfacing rural roads. Molding and building sands are dredged from the beds of the Ohio, Tennessee, and Mississippi Rivers.

In the past, Pleistocene loess was used in the manufacture of brick at Paducah, Mayfield, and Fulton.

GEOLOGY

The rocks exposed in the Jackson Purchase range in age from Devonian to Recent. Most of the area is underlain by strata of sand, clay, and gravel of Tertiary age. The eastern part of the area is underlain by Cretaceous sand, clay, and gravel and Paleozoic limestone and chert. The rocks are described in order from oldest to youngest. The outcrop areas of the various rock units are shown on figures 4 and 5; cross sections of the geologic units are given in figures 6–9.

STRATIGRAPHY

PALEOZOIC

The oldest rocks exposed in the Purchase are of Devonian age and are found in a fault zone along Little Bear Creek in Marshall County. The Camden chert and the Jeffersonville limestone are exposed for about a quarter of a mile along the embayment that leads from the creek into Kentucky Lake. These formations, described by Luttrell and Livesay (1952), have only a small area of outcrop and are of little significance to the ground-water hydrology of the region.

The Fort Payne chert of Mississippian age crops out in a narrow area along the west shore of Kentucky Lake from the Blood River northward to within 3 miles of Kentucky Dam. It is 515 feet thick in a drill hole at the dam and 300 feet thick at Eggners Ferry to the south. The Fort Payne in this region is typically a dark bluish-gray nonfossiliferous limestone containing dark-blue to black banded chert. Some weathered sections consist of bleached chert with thin beds of clay or tripolite.

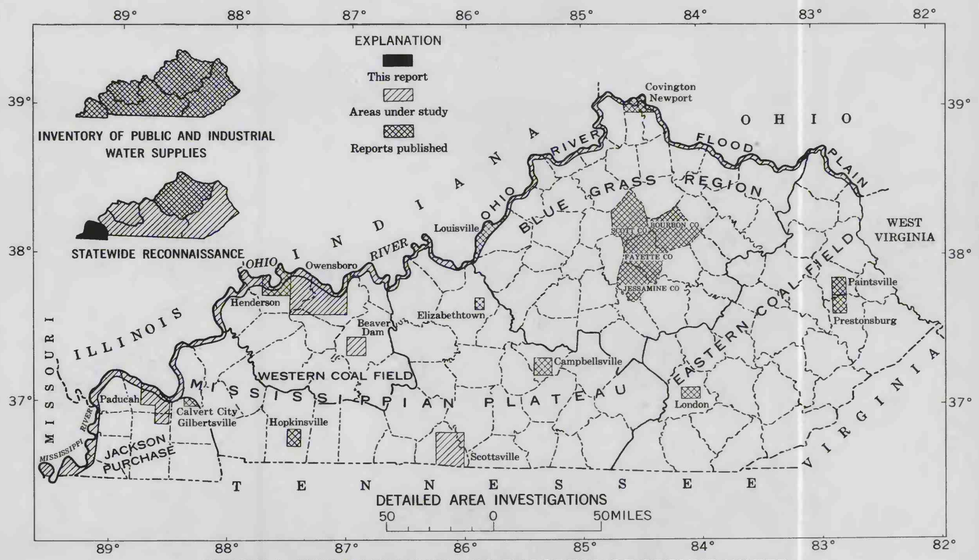

FIGURE 1—INDEX MAP SHOWING PROGRESS OF GROUND-WATER INVESTIGATIONS IN KENTUCKY

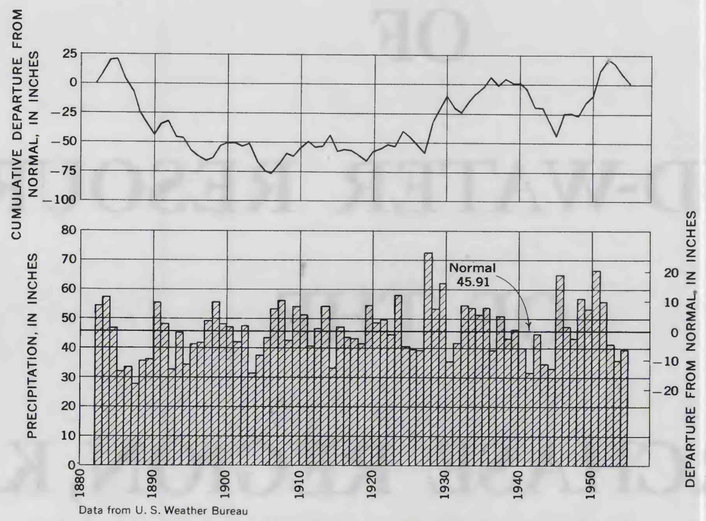

FIGURE 2—ANNUAL PRECIPITATION AND CUMULATIVE DEPARTURE FROM NORMAL PRECIPITATION AT PADUCAH, KENTUCKY

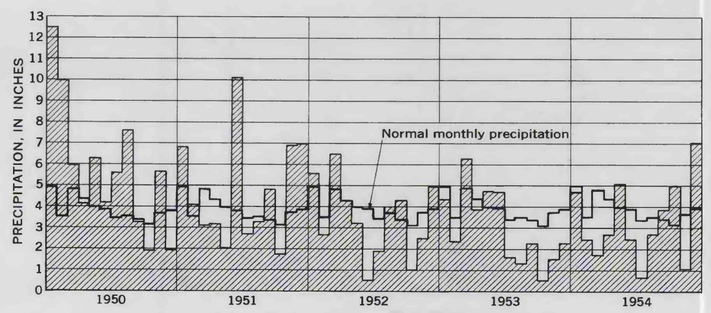

FIGURE 3—PRECIPITATION AT PADUCAH, KENTUCKY, 1950–54

The Fort Payne chert yields water to some wells along Kentucky Lake. The well at Kentucky Lake State Park produces approximately 60 gpm (gallons per minute) from this formation. The water is probably transmitted mainly through fractures in the chert.

The Warsaw limestone, also of Mississippian age, crops out at a few localities along Kentucky Lake. A good exposure on the west side of the lake is a few hundred feet south of the foot of the old road to the abandoned village of Birmingham. The Warsaw at this exposure is a gray crystalline fossiliferous limestone containing thin beds of chert. The limestone weathers to a nearly white honeycombed surface. Only a few feet of the formation is exposed above the high water level of Kentucky Lake.

A few wells along Bear Creek in Marshall County produce water from the Warsaw limestone. Fractures in the limestone are enlarged by solution adjacent to exposures, and the ground water is transmitted through these openings.

The St. Louis limestone of Mississippian age crops out in a few places west of Kentucky Lake. There is one exposure of dark-gray limestone and nodules of chert in a road cut near Kentucky Dam Village State Park. The St. Louis is a medium- to thick-bedded semilithographic dark-gray to black limestone containing thick beds of yellowish chert. The St. Louis underlies the area from Kentucky Dam to Calvert City and supplies water to wells drilled into it.

Mississippian rocks of Chester age probably underlie part of the Jackson Purchase near Paducah. The Tar Springs sandstone is exposed on the north bank of the Tennessee River about 7 miles upstream form Paducah, outside the Purchase. Rocks of Chester age have been reported in an oil test hole drilled in Paducah. These rocks probably are of minor importance as a source of ground water.

CRETACEOUS

The Tuscaloosa formation is the oldest Cretaceous deposit in western Kentucky. It is best exposed along Kentucky Lake in Marshall County. There is one small exposure on the shore of the lake at Hickory Point, and others are present near the tops of the ridges between Bear Creek and the lake. The Tuscaloosa is as much as 200 feet thick at Golden Pond in Trigg County, but probably less than 30 feet is exposed west of Kentucky Lake.

The Tuscaloosa is composed of well-rounded chert gravel in a matrix of sand and some clay. The particles of gravel range from ¼ inch to 10 inches in diameter and average 1½ inches. Marine fossils reworked from Paleozoic rocks are found in the Tuscaloosa.

The Tuscaloosa yields a small amount of water to wells in Marshall County. Yields are generally low owing to the presence of a clayey matrix.

Investigations by Moneymaker and Grant (1954) indicate that much of the basal Cretaceous gravel in the Purchase is younger than the Tuscaloosa. This later gravel is probably of late Selma or early Ripley age.

The Ripley formation, which overlies the Tuscaloosa, is exposed in Calloway and Marshall Counties, where it crops out in a belt paralleling Kentucky Lake. The Ripley in outcrop is nowhere more than 70 feet thick and in most exposures is 20 to 30 feet thick. The formation is covered by a thick mantle of Pliocene(?) gravel and Quaternary alluvium in McCracken and Ballard Counties. As much as 400 feet of Ripley has been penetrated in oil test holes drilled in the Jackson Purchase.

The Ripley formation is typically unconsolidated sand and interbedded clay but contains many thin beds of sand and clay cemented with iron oxide. The sand may be white, buff, yellow, or red, and the clay may range from white to dark gray. Marcasite concretions occur in the clay, and in some places leaf prints are found. In many exposures the sand is feldspathic and contains much white mica. In much of Marshall, McCracken, and Ballard Counties the Ripley is mostly clay and silt, but thin beds of sand are present near the base.

Where the Ripley is composed mostly of unindurated sand, it yields large quantities of water to wells. In areas where the Ripley is composed mostly of clay and silt, it may yield practically no water.

TERTIARY

Paleocene.—The Porters Creek clay of Paleocene age is exposed in a narrow arcuate belt extending from the Tennessee line northward through Calloway County and then northwestward across Marshall and McCracken Counties. There are no exposures in Ballard County because thick deposits of gravel of Pliocene(?) age and river alluvium cover the Porters Creek clay. The clay is 140 to 160 feet thick in the eastern half of the Jackson Purchase and thickens to 350 feet in the west. Most exposures reveal no more than 40 feet of the clay. The Porters Creek is a light- to slate-gray clay of very fine texture containing thin beds of mica flakes and very fine sand between laminae of clay. It is slippery when wet and dries into rectangular blocks.

In many exposures the Porters Creek clay is cut by random dikes of sand and sandstone as much as 2 feet wide and 50 feet long. In some places the thin beds of sand and the dikes contain a few casts of marine gastropods and pelecypods.

The Porters Creek clay probably will yield a little water from beds and dikes of sand and perhaps will yield some from joints. Groundwater circulation in the formation is poor, and the water may be hard and high in iron content.

Eocene.—Sand and clay of Eocene age underlie most of the Purchase west and south of the outcrops of the Porters Creek clay. There are few exposures of the Eocene deposits, owing to the presence of a mantle of gravel of Pliocene(?) age and loess of Pleistocene age over most of the western counties. As much as 30 feet of Eocene deposits is exposed in roadcuts and gullies. The Eocene deposits have a maximum thickness of 700 feet in oil test holes in Fulton County. They are composed of sand and include some layers indurated by iron oxide cement, clay, and a basal clayey conglomerate. The sand is fine to coarse and is composed chiefly of rounded quartz grains; feldspar, mica, and iron oxide also are present. Large lenses and beds of clay are mined at several localities. The clay may be white, yellow, gray, or dark brown and in places contains coarser material that gives it a gritty texture. White-burning clay is mined and shipped to manufactures of ceramics. Lignite is usually present in the clay, and concretions of marcasite are common.

The sand and clay of the Eocene interfinger in such a manner that a sand bed in one exposure may be correlative with a clay bed a few hundred feet away. The vertical and lateral ranges in lithology in the Eocene deposits make it difficult to predict the depth to productive aquifers. In many areas a productive sand lies in the uppermost 300 feet of the deposits, but in some places the shallow zones will not yield sufficient water for large users. A shallow aquifer at Fulton will yield as much as several hundred gallons per minute to individual tubular wells, but municipal and industrial wells are drilled to 600 feet to obtain larger amounts of water.

Pliocene(?).—Much of the upland surface of the Jackson Purchase is covered by a mantle of gravel and sand of Pliocene(?) age. The maximum thickness of the Pliocene(?) deposits is probably more than 50 feet, and the average is about 25 feet. The gravel consists mostly of subangular to rounded particles of chert, but some pebbles are quartzite. Many of the pebbles are 2 to 3 inches in diameter, but most are between ½ and 1 inch. The sand is medium to coarse grained and is composed of quartz and chert and some feldspar and hornblende. The sand may occur as a matrix in gravel or as separate layers. In many places, pebbles and sand grains are both stained and cemented together by iron oxide.

The gravel of Pliocene(?) age yields water to many shallow wells in the Jackson Purchase. The water moves chiefly through the unconsolidated sand and gravel. In many places it is perched or semiperched by beds of clay or indurated sand and gravel.

QUATERNARY

Pleistocene loess.—Thick deposits of loess occur along the Mississippi River bluffs in the Purchase. These deposits are approximately 40 feet thick on the bluffs and thin gradually away from the river. The loess is less than 10 feet thick in most of Graves County and gradually merge with a loamy soil in Calloway County. Along the Ohio River in McCracken County the loess reaches a maximum thickness of 20 to 25 feet. The loess is composed of angular silt-sized particles of quartz and small amounts of feldspar and mica. Calcareous concretions and small pebbles are common in some of the deposits of loess. The loess has vertical jointing which is responsible for the steep to vertical slopes in exposures along the river bluffs and in road cuts.

The loess is of little importance as an aquifer as it is fine grained and compact. The presence of mollusk shells and calcareous concretions may explain the high bicarbonate content of water from aquifers that lie beneath the loess.

Pleistocene and Recent alluvium.—Extensive deposits of gravel, sand, and clay occur along the flood plains of the Tennessee, Ohio, and Mississippi Rivers. Approximately 80 feet of alluvium was penetrated in the valley of the Tennessee River near Kentucky Dam, and bridge borings near Paducah penetrated 100 feet of alluvium in the Ohio River flood plain. The thickness of alluvium along the Mississippi River probably is more than 100 feet. Except for thin beds of fine sand and layers of mud along the river banks, there are few good exposures of alluvial deposits in the Purchase. Along the large rivers the alluvium ranges from coarse gravel to clay, but along the small streams it is mostly fine sand, silt, and clay.

As much as 300 gpm is pumped from single wells penetrating alluvial deposits in Ballard County, and many small domestic supplies come from the alluvium in Fulton County. The alluvium in the small stream valleys is fine grained and clayey, and wells penetrating it have small yields.

STRUCTURE

The Jackson Purchase lies in the extreme northeastern part of the Mississippi embayment. Structurally the embayment is a downwarped trough (geosyncline) of Paleozoic rocks which has been filled with Cretaceous and younger sediments. The Cretaceous and the overlying Tertiary strata deposited in the embayment become progressively thicker to the southwest. The outer rim of the embayment is delineated by outcrops of Paleozoic rocks. Dips in the Cretaceous, Paleocene, and Eocene beds are 20 to 30 feet per mile to the south and west. There is no observable dip in the Pliocene(?) and Quaternary deposits.

There is evidence that faulting similar to that exposed in the Kentucky fluorspar area has displaced the Paleozoic bedrocks beneath the Purchase. With more detailed information, some of the peculiar features delineated on the structure map on the base of the Cretaceous (top of the Paleozoic) might be shown to be due to faulting. Faulting and other structural features of the area are discussed by Freeman (1950, 1951, 1953).

GEOLOGIC HISTORY

During the Paleozoic era, most of the interior of North America was covered by a vast changing sea. Sediments were deposited in geosynclines and embayments during times of flooding by the sea and were eroded when the sea receded. These transgressions and regressions of the sea throughout the Paleozoic resulted in deposition of alternating limestone, sandstone, and shale.

Formation of the Mississippi embayment began during the Cretaceous period with a downwarping of the Paleozoic surface, which allowed the sea to move northward. Coarse sand and gravel were deposited near the shores of the embayment; finer sediments were carried offshore and deposited as beds of silt and clay. At even greater distances from the shore, limestone was formed. Toward the close of the Cretaceous the sea began to recede and became very shallow, so that most of the deposited material was exposed to wave action, which produced crossbedding in the Ripley formation.

During the Paleocene epoch the sea began to encroach upon the land again, and glauconitic sand was deposited in the Mississippi embayment. The sea continued to deepen, and fine-textured marine clay of the Midway group was deposited. At the close of Midway time the sea receded and estuarine and littoral conditions prevailed. The sandbeds and clay lenses of the Eocene series were deposited at this time. By the end of Eocene time the region was dry land and subject to erosion; however, it was not reduced to a peneplain. During the Pliocene epoch the somewhat irregular erosion surface was lowered slightly, and heavily laden streams deposited sand and gravel as they made their way to the sea. Probably most of the irregularities in the pre-Pliocene surface were covered by this sand and gravel.

In the Pleistocene epoch the northern part of North America was covered by vast continental ice sheets. As the glaciers melted, large amounts of sand, gravel, and rock debris were carried down the rivers and deposited as alluvium. Some of the material was reworked by water and wind, the latter carrying silt to form loess along the Mississippi and Ohio Rivers.

GROUND WATER

HYDROLOGIC CYCLE

Most water of economic importance in the Jackson Purchase region comes from local precipitation and from rivers flowing through the region. Rainfall or snowmelt soaks into the ground until the soil reaches field capacity. After the soil reaches field capacity, or even before when the rate of rainfall or snowmelt exceeds the infiltration capacity of the soil, water runs off over the surface to streams or ponds. Part of the water that enters the soil is evaporated directly, part is held by capillary forces until transpired by plants, and still another part—water entering the soil in excess of field capacity—seeps downward to be added to the ground-water body. The water in the ground-water body slowly seeps toward points of lower elevation, and eventually it discharges through springs or seeps into streams or is transpired by vegetation along the streams. The seepage and spring flow are the source of most of the base flow of streams during dry weather. The hydrologic cycle is extremely complicated and is affected and controlled by precipitation, temperature, nature of the soil, topography, plant cover, and geology.

If no net change occurs from 1 year to the next in the amount of water stored underground (ground water plus soil water), and if no underground flow bypasses the streams, the amount of stream runoff plus the amount of water lost by evapotranspiration is equal to the annual precipitation in a given area. In the Jackson Purchase region the annual rainfall is about 46 inches, and the average annual runoff is about 17 inches. Therefore, the average annual loss of water by evaporation and transpiration appears to be about 29 inches, or 63 percent of the average precipitation. Actually, some water moves down the dip in the Coastal Plain strata and bypasses the streams of the Jackson Purchase, so that the evapotranspiration from the Purchase is less than 29 inches. How much less is not known, but the ground-water outflow from the region, though large on an absolute scale, probably is not large enough to reduce the figure of 29 inches by any large amount.